DOCUMENT RESUME

ED 354 810 HE 026 229

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TITLE Prospects for Integrating Reliability and Maintainability into Undergraduate Engineering Curricula. Final Technical Paper for Period June-December 1989.
INSTITUTION Air Force Human Resources Lab., Brooks AFB, Texas.; Systems Exploration, Inc., Dayton, OH.
REPORT NO AFHRL-TP-90-5
PUB DATE May 90
CONTRACT F33615-88-C-0004
NOTE 28p.; Summary of Proceedings of the RAMCAD Engineering Curriculum Workshop (Arlington, VA, June 14-15, 1989).
PUB TYPE Collected Works - Conference Proceedings (021) -- Information Analyses (070)

EDRS PRICE MF01/PC02 Plus Postage.
DESCRIPTORS College Faculty; *Computer Assisted Design; Computer Assisted Manufacturing; *Curriculum Design; Curriculum Development; *Engineering Education; Equipment Maintenance; Higher Education; *Reliability; Undergraduate Study
IDENTIFIERS *Air Force Human Resources Laboratory

ABSTRACT

The "RAMCAD" workshop summarized in this document reviewed the prospects for integrating reliability and maintainability into undergraduate engineering curricula. RAMCAD stands for Reliability, Availability, and Maintainability in Computer-Aided Design. The workshop was sponsored by Air Force human resources departments and attended by a cross-section of university faculty members, industrial organizations, and other Air Force organizations. The paper briefly describes the goals and organizational format for the workshop and then provides synopses of participants' presentations and panel discussion. A final section offering conclusions observes that because academic and government participants disagree as to the best approach for integrating reliability and maintainability into the engineering curriculum, and due to the complexity of the issues, none of the suggestions discussed at the workshop promise to be effective in the near term though they may have significant impact by the turn of the century. Appendixes list participants and contain the workshop agenda. (JB)

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AFHRL-TP-90-5

AIR FORCE HUMAN RESOURCES LABORATORY

PROSPECTS FOR INTEGRATING RELIABILITY AND MAINTAINABILITY INTO UNDERGRADUATE ENGINEERING CURRICULA

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May 1990

Final Technical Paper for Period June - December 1989

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The Public Affairs Office has reviewed this paper, and it is releasable to the National Technical Information Service, where it will be available to the general public, including foreign nationals.

This paper has been reviewed and is approved for publication.

BERTRAM W. CREAM, Technical Director
Logistics and Human Factors Division

JAMES C. CLARK, Colonel, USAF
Chief, Logistics and Human Factors Division

REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

Public reporting burden for this collection of information is estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden, to Washington Headquarters Services, Directorate for Information Operations and Reports, 1215 Jefferson Davis Highway, Suite 1204, Arlington, VA 22202-4302, and to the Office of Management and Budget, Paperwork Reduction Project (0704-0188), Washington, DC 20503.

1. AGENCY USE-ONLY (Leave blank)	2. REPORT DATE	3. REPORT TYPE AND DATES COVERED
	May 1990	June - December 1989

4. TITLE AND SUBTITLE

Prospects for Integrating Reliability and Maintainability into Undergraduate Engineering Curricula

5. FUNDING NUMBERS

C - F33615-88-C-0004
PE - 62205F
PR - 1710
TA - 00
WU - 40

6. AUTHOR(S)

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8. PERFORMING ORGANIZATION REPORT NUMBER

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)

Logistics and Human Factors Division
Air Force Human Resources Laboratory
Wright-Patterson Air Force Base, Ohio 45433-6503

10. SPONSORING/MONITORING AGENCY REPORT NUMBER

AFHRL-TP-90-5

11. SUPPLEMENTARY NOTES

12a. DISTRIBUTION/AVAILABILITY STATEMENT

Approved for public release; distribution is unlimited.

12b. DISTRIBUTION CODE

13. ABSTRACT *(Maximum 200 words)*

This paper summarizes presentations and discussions of academic, industrial, and Air Force representatives whose goal is to implement supportability concepts into undergraduate engineering curricula. Individual examples of success stories from several schools are presented, contrasted with the reluctance exhibited by the academic community in general to follow these initiatives.

14. SUBJECT TERMS

curriculum
engineering
maintainability
RAMCAD
reliability
supportability

15. NUMBER OF PAGES

28

16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT	18. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT
Unclassified	Unclassified	Unclassified	UL

AFHRL Technical Paper 90-5 May 1990

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Submitted for publication by

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This publication is primarily a working paper. It is published solely to document meeting proceedings.

SUMMARY

This paper documents the results of the "RAMCAD Engineering Curriculum and Development Workshop" sponsored by the Air Force Human Resources Laboratory and assisted by Systems Exploration, Inc. in conjunction with a cross-section of university faculty members, industrial organizations, and other Air Force organizations.

Participants from eight engineering departments reported significant progress toward incorporating reliability and maintainability concepts into their undergraduate curricula. The Air Force has underwritten much of this work in order to develop model curricula which other engineering departments may emulate. Academia as a whole, however, has been slow to develop interest.

The workshop thus focused on strategies to motivate near-term widespread academic involvement. Academic and Government participants disagreed as to the best approach. Due to the complexity of the issues, none of the suggestions promise to be effective in the near term. By the turn of the century, however, current initiatives should have significant impact. Model curricula will become increasingly important; thus, their development must continue.

PREFACE

The Logistics and Human Factors Division of the Air Force Human Resources Laboratory is conducting ongoing research to improve the weapon system designer's "toolbox" to enable insertion of reliability and maintainability into the initial phases of weapon system design. System desginers must be literate in supportability concepts in order to use such tools, yet most design engineers gain such knowledge retroactively on the job, if at all. Few undergraduate college curricula include solid foundations in reliability and maintainability.

The division has thus included development of prototype undergraduate supportability curricula in its overall Reliability, Availability, and Maintainability in Computer-Aided Design (RAMCAD) research program. After a series of workshops to plan the development of such curricula, the division sponsored this workshop to discuss widespread implementation. It served as a forum to assess the current status of development efforts and to openly discuss motivational strategies for academia.

TABLE OF CONTENTS

		Page
I.	PURPOSE	1
II.	INTRODUCTION	1
	Basic Approach	1
	The Workshop Approach	2
	Workshop Description	2
	Attendance	2
	Agenda	3
III.	WORKSHOP SYNOPSIS	3
	Air Force	3
	Industry	6
	Academia	7
	Panel Discussion: All Participants	12
IV.	PROSPECTS FOR CURRICULA INTEGRATION	12
V.	SUMMARY	14
	APPENDIX A: LIST OF ATTENDEES	15
	APPENDIX B: AGENDA	17

I. PURPOSE

This paper documents the results of the "RAMCAD Engineering Curriculum Development Workshop" sponsored by the Air Force Human Resources Laboratory (AFHRL) and assisted by Systems Exploration, Inc. (SEI) in conjunction with a cross-section of university faculty members, industrial organizations, other government agencies, and other Air Force organizations.

II. INTRODUCTION

Basic Approach

The Logistics and Human Factors Division of AFHRL is conducting ongoing research to improve the weapon system designer's "toolbox" to enable insertion of Reliability and Maintainability (R&M) into the initial phases of weapon system design. Fundamental to the successful use of such tools are their users. The system designers must be literate in supportability concepts in order to use such tools. Few undergraduate college curricula include solid foundations in R&M, human engineering, systems safety, electromagnetic compatibility, corrosion control, or the other "-ility" related topics in their mainstream engineering programs.

AFHRL has included the development of prototype undergraduate supportability curricula in its overall Reliability, Availability, and Maintainability in Computer-Aided Design (RAMCAD) research program. So far, this effort has included:

1. Conducting curricula development workshops (research and information gathering),
2. Preparing a curricula development plan (data analysis and synthesis), and
3. Preparing and evaluating a prototype curricula (program development and evaluation).

These workshops involved representatives of 24 universities, 33 industrial concerns, and 7 government organizations. The results of Workshops I through V have been documented by Virginia Polytechnic Institute (VPI) and SEI reports and are on file at AFHRL.

The Workshop Approach

Originally, AFHRL planned this workshop to build upon the work previously accomplished and to present progress in curricula development to a broad industrial and academic audience. Two factors changed this focus:

1. The Laboratory grew concerned about the willingness of academia to participate; i.e., to continue to develop supportability curricula or to even use the prototype material once available.

2. The Laboratory decided that other Air Force organizations should be involved. It held a series of meetings with USAF LE-RD, the Electronic Systems Division, the Rome Air Development Center (RADC), and the Air Force Institute of Technology (AFIT) to develop an overall Air Force objective.

The focus thus shifted from the curricula itself to curricula implementation. The workshop then would present status reports on curricula development, but would emphasize the importance of using the curricula. The objective was to solicit more nongovernment participation in curricula development and application, to balance "curricula push" with more "curricula pull."

Workshop Description

The workshop (15-16 June 1989) was held in Arlington, Virginia. Invitations were sent to 24 academicians, 12 industrial representatives, and the National Science Foundation. In context of the Air Force objectives, a dual theme was described:

1. Engineering Education for the 1990s
2. Integrating Quality through R&M Dimensions

Attendance

The workshop had an excellent mix of backgrounds. There were 12 academicians representing eight universities, 10 industrial representatives from four corporations, one industrial association and two non-profit groups, and 14 government personnel. Appendix A contains a complete list of attendees. This blend

of backgrounds contributed to an excellent interchange of ideas, concepts, and serious discussions.

Agenda

The agenda was designed to promote participant information exchange. It provided major blocks of time for:

1. The Air Force to detail its goals and objectives in sponsoring the workshop,
2. Industry to detail its engineering needs for the future, and
3. Academia to discuss its efforts in enhancing the current curriculum, its development efforts for the future, and its perceptions of the government and industry's needs.

A copy of the agenda is provided in Appendix B.

III. WORKSHOP SYNOPSIS

This section provides an overview, and the essence of selected presentations and discussions which accompanied them.

Air Force

GENERAL WILLIAM COLLINS, SPECIAL ASSISTANT FOR R&M, USAF/LE-RD, PENTAGON, WASHINGTON, D.C.

The Air Force depends on U.S. industry for its ability to provide adequate defense of the country. In periods of budget cuts, such as we will continue to face for some time, increased R&M and quality of Air Force procurements is an absolute must. Today's equipment must work the first time and continue to work. We can't afford the spares inventory we have maintained in the past. In the future, we must train new engineers coming into the workforce to consider R&M, quality, supportability, and operability during equipment design and manufacturing. Academia must recognize our needs and help us solve this educational problem over time; not tomorrow, but certainly in the near term.

COLONEL JAMES HARRINGTON, DEPUTY FOR R&M, USAF/LE-RD, PENTAGON, WASHINGTON, D.C.

The Air Force is driving to meet the R&M 2000 goals and to assure that we have the capability for "performance on demand" to meet any defense requirement. To support this goal, we are educating our Air Force management team in total management involvement, individual motivation, an understanding of the requirements process, the importance of preserving an audit trail of design decisions, and the importance of the design decisions themselves. We are working to enhance the entire Air Force weapons system life cycle management process by placing added emphasis on our basic building blocks:

1. Robust design, which translates operational requirements to engineering requirements, and
2. The importance of process control and quality as a foundation for successful weapons system deployment and supportability.

Academia is a key part of this building block concept as they educate the engineers with the tools which form the basis for our building blocks. They must rise to the challenge in evolving their curricula to meet industry and government needs.

MAJOR DON LOWDERMILK, PROJECT MANAGER, AFHRL, WPAFB, OH

The Air Force has developed a team approach to the problem of engineering education for the 1990s. That team includes USAF/LE-RD, the United States Air Force Academy (USAFA), the Rome Air Development Center (RADC), the Wright Research and Development Center (WRDC), the Electronics Systems Division (ESD), the Air Force Human Resources Laboratory (AFHRL), and the Air Force Institute of Technology (AFIT). The Air Force is concerned with both the short- and long-term efforts necessary to improve engineering education. Its goals include an improved engineering curriculum and the integration of supportability into the design environment. Approaches include conducting RAMCAD studies and workshops, developing electrical engineering curricula at the Florida Institute of Technology (FIT) and USAFA, establishing a Center of Excellence for R&M at AFIT, and sponsoring engineering faculty to attend summer R&M workshops through AFIT. The team approach has been instrumental in the establishment and conduct of today's workshop. Future efforts will include an AFHRL/RADC-sponsored model curriculum

development by VPI and the Florida Institute of Technology (FIT), culminating in a seminar/workshop in February 1990 for the deans of key engineering schools.

MR. JERRY KLION, RADC/RBET,GRIFFISS AFB, NY

One of RADC's major objectives has been to enhance readiness and support of the Air Force through increased application of R&M across the full spectrum of their activities. One major activity has been the sponsored research ongoing between USAFA and FIT. USAFA has been functioning as a consultant and beta site for the integration of curricula enhancements relating to R&M and technology innovation into the electrical engineering area, RADC will continue this support through the research for the planned February 1990 workshop for the deans of selected engineering programs.

DR. BEN WILLIAMS, DIRECTOR, CENTER OF EXCELLENCE FOR R&M, AFIT, WPAFB, OH

AFIT has long recognized the need for integrating R&M into the engineering environment, at both the graduate and undergraduate levels. One of its major efforts has resulted in adding an additional quarter of study at AFIT for reliability engineering. It has established the Center of Excellence for Reliability and Maintainability to foster and promote applications in future academic efforts. AFIT has also recognized the need to assure that academic faculty members have an appreciation for the impact of R&M as a design engineering skill and has conducted summer faculty workshops to meet this need. It has established an R&M and quality day at AFIT to promote the recognition of the role of these functions in academia and industry. AFIT is also an active committee member of the Accreditation Board for Engineering and Technology. It will continue to act as a member of the Air Force advisory group on academia and will participate as required in the February 1990 workshop for the deans of engineering.

MAJOR BILL SKEITH, MATH DEPARTMENT, USAFA, COLORADO SPRINGS, CO

The Vice Chief of Staff Policy Letter #6, July 1988, directed increased education and training in skills necessary to support USAF initiatives for improved weapon system quality and R&M without unnecessary increases in cost. The Academy is responding with alacrity to this direction. Major Skeith is the USAFA R&M focal point for "Quality through R&M." He described the efforts of the Academy to integrate reliability and experimental design courses into its engineering curricula. One

success is the Electrical Engineering Departments Senior level core design course. It brings statistics and engineering design students together, opens communications between the Engineering and Mathematical Sciences departments, allows engineers and statisticians to understand each others' viewpoints, and improves the design of empirical experiments. The Academy has also initiated "Blue Two" visits to operating Air Force bases for cadets between their Junior and Senior year, so that the field experiences they gain can be used in their work in the core design course. The Academy's work with FIT has been a positive experience in examining new ways to improve and expand the basic curricula. Its role as a consultant and beta site will continue.

Industry

PAUL GIORDANO, PRESIDENT - GIORDANO ASSOCIATES, MEMBER NSIA, ARLINGTON, VA

Mr. Giordano represented both his company and the National Security Industry Association (NSIA) as he discussed "Engineering Education for the 1990s, Needs for the Future, an Industry View." The "gut issue" is systems engineering, i.e., the "holistic" approach which considers all aspects of the weapon system during its life cycle, influenced strongly by the design process, and impacted by the cost of supportability throughout the life cycle. In a period of budget reductions and priority spending, the Air Force must realistically assess its needs and make every effort to reduce its airlift requirement, operations and support (O&S) costs, maintenance costs/manpower, and I-level maintenance. The vulnerability of overseas Air Force bases has caused a need to reassess its I-level maintenance concepts. Within this framework, weapon system quality and support have become national issues which the Air Force and industry must address. Technology, driven by mission needs, has changed the basic nature of weapon systems, and NSIA's members (375 companies and 8500 individuals) are directing their efforts to improving:

1. Diagnostic capability;
2. Acquisition methodology;
3. Communications between industry, government, and academia;
4. Integration of disciplines, program phases, maintenance, tools, etc.; and

5. Concurrent engineering, which is the process of integrating design, manufacturing, and support.

The "bottom line" is that academia, industry, and government must work as a team to meet these goals. NSIA feels that systems engineering must be taught in the 1990s with a holistic approach, involving industry, government, and academia, so that the order of magnitude improvements can be made in system supportability and life cycle costs.

Academia

DR. EDWARD W. ERNST, PRESIDENT (ELECT) ABET, AND ABET PROGRAM DIRECTOR FOR UNDERGRADUATE ENGINEERING EDUCATION; NATIONAL SCIENCE FOUNDATION (NSF), WASHINGTON, D.C.

The Accreditation Board for Engineering and Technology (ABET) is made up of 21 participating Engineering Societies. Its Engineering Accreditation Commission (EAC) is vitally concerned with the continuing development and improvement of curricula. Its evaluation criteria consider six major facets of a program: faculty, curriculum, students, administration, facilities, and institutional commitment. It thoroughly reviews the program criteria by discipline. It evaluates each curriculum's content in basic sciences, mathematics, engineering science, and engineering design. Engineering design includes laboratory experience, computer experience, communication skills, ethics, social sciences, economics, and safety. ABET strongly encourages positive interaction between academia and its customers, industry and government. ABET strongly encourages the kind of dialogue taking place within this workshop and is very willing to support such efforts in the future.

DR. JOHN HADJILOGIOU, DEPARTMENT OF ELECTRONICS AND COMPUTER ENGINEERING, FLORIDA INSTITUTE OF TECHNOLOGY (FIT), MELBOURNE, FL

FIT currently has an aggressive program for integrating reliability, maintainability, and quality into the undergraduate curriculum of its electrical and computer engineering departments. Its current implementation methodology contains the following steps:

1. Review academic requirements, including ABET accreditation criteria.
2. Examine these criteria in light of previous workshop efforts.

3. Develop pilot curriculum with detailed curricula, course syllabi, and descriptions of the material.

4. Test the pilot curriculum in classrooms.

5. Conduct a workshop to describe the curriculum and test results and discuss implementation.

6. Review and evaluate workshop results.

7. Prepare a prototype curriculum guide with program plans, materials, and bibliography.

8. Review all material, then distribute the guide for program implementation.

FIT has developed supplemental reliability material for 10 key areas and has planned an integration schedule to introduce this material into 11 core courses, beginning in the summer quarter of 1989 and extending through the summer quarter of 1991.

FIT has developed supplemental testability material for nine key areas and has set an implementation schedule covering the same school years described above.

FIT is also developing a senior year course for the management and control of quality. This course will cover the areas of statistics, product design, reliability, statistical process control, and control charts.

FIT is developing a "House of Quality" approach to increase the quality of the engineering curriculum in the 1990s. The thrust of this effort is to determine the needed material, to develop material which is not currently available, and to integrate this material in the model engineering curriculum. Its purpose is to develop a model that provides guidelines for educating a quality engineer for the 1990s, an engineer capable of meeting changing and future needs. This approach requires the participation and support of the entire faculty and staff and a closer working relationship among the academic, industrial, and governmental communities.

This approach closely relates to and facilitates the task that FIT and VPI have undertaken to develop and disseminate model curricula for discussion with the deans of engineering schools in February of 1990.

PROFESSOR BEN BLANCHARD, ASSISTANT DEAN, ENGINEERING EXTENSION, COLLEGE OF ENGINEERING, VIRGINIA POLYTECHNIC INSTITUTE (VPI), BLACKSBURG, VA

Professor Blanchard described VPI's efforts at developing curriculum supportive of the RAMCAD thrust. VPI conducted a series of five workshops involving academia and industry. These workshops looked at curricula requirements, commercially available computer design tools, industrial efforts to integrate RAMCAD tools, demonstrations of industry tools, and a demonstration of academia's use of RAMCAD tools. VPI's efforts have involved 14 other universities and a cross-section of the industrial community. VPI's curricula development process parallels that described by the FIT above, with only a minor variance relating to classroom testing. VPI chose to look at classroom applications in the abstract rather than at an actual classroom test of the curricula and syllabi. They have developed several prototype curricula, an evaluation of where changes could be initiated in current core courses, and a significant evaluation of the currently available computerized training aids and tools which can be integrated into the curriculum. VPI also looked at the applicable levels for the most practical applications of RAMCAD technology in the curricula, i.e., graduate versus undergraduate and continuing education programs. They defined a place for each in their overall schema. VPI feels that future success in the curricula area depends upon a demonstrated continuing interest by the "user" community (industry and government), the availability of RAMCAD tools for use in the academic environment, the motivation of the accreditation team members (EAC/ABET), and the motivation of the faculty of specific engineering schools. VPI has been designated to work with FIT as required to prepare for the February conference.

DR. MIKE PECHT, MECHANICAL ENGINEERING DEPARTMENT, UNIVERSITY OF MARYLAND, COLLEGE PARK, MD

Dr. Pecht described the University of Maryland's (UM) experience and efforts to promote reliability education in the engineering environment. UM has developed an integrated program to encourage and assist the corporate industrial base to field systems with high reliability and availability. It has a mix of academic and research programs that recognizes the value of designing for reliability and maintainability and the importance of producibility and statistical process control in reducing manufacturing defects. Its stated goal is to equip engineers with the means to deal with reliability issues rather than to train "reliability engineers." At the undergraduate level, UM has introduced reliability courses into the Mechanical,

Electrical, Civil, Chemical, and Nuclear Engineering departments. At the graduate level, it has provided a three-part curriculum dealing with basic, advanced, and specialty courses related to the reliability disciplines. UM is also actively participating in research within the Computer-Aided Logistics Support (CALS) area, having major research projects related to RAMCAD, concurrent engineering, and other systems integration areas with Westinghouse, Lockheed Georgia, TRW, RADC, and IBM. Its overall approach has been to develop fundamentals at the undergraduate level and to complement and enhance the engineering skills at the graduate level with a well-planned mix of academic requirements and targeted research aimed at satisfying national, corporate, and government needs.

DR. WOLT FABRYCKY, DEPARTMENT OF INDUSTRIAL ENGINEERING AND OPERATIONS RESEARCH, VIRGINIA TECH, BLACKSBURG, VA

Dr. Fabrycky described the actions he has been taking in his look at "RAMCAD in Academia." He discussed the basic methodology to evaluate the current curricula, areas and issues related to RAMCAD which should influence a curricula redesign effort, concepts which should be evaluated, how to define requirements, how to develop prototypes, and how to document and implement such a program. He reiterated the point made by many of the speakers that successful implementation of an engineering curricula change requires a "team approach," involving not only faculty members, but corporate and federal organizations who are the end users of the university's product -- the engineer. He also stated that academia and the government could collectively work through the National Science Foundation to conduct research in areas such as "Design Theory and Methodology." This type of research and funding has a very direct impact on changes to be introduced into engineering curricula. He stated that a "Mansfield-type" mandate from DoD regarding project contracts with universities, forcing the inclusion of "supportability impacts," could also accelerate the revision of curricula. He concluded that academic faculty could also influence their contemporaries and peers by publishing papers, articles, and texts concerning the latest developments in R&M issues and methods for implementing solutions for these issues. The bottom line was that academia, industry, and government must work together if the R&M issues are to become basic tools of the engineer of the 1990s, and that this cooperation must include some level of funding for academic research.

DR. JOHN BOWLES, ELECTRICAL AND COMPUTER ENGINEERING DEPARTMENT, UNIVERSITY OF SOUTH CAROLINA, COLUMBIA, SC

Dr. Bowles discussed the importance of using the continuing education approach as well as the traditional curricula change methodology to introduce new concepts into the engineer's "toolkit." He described the Reliability and Maintainability Society's (RAMS) "Engineering Education Workshop," which will be held in January 1990 in conjunction with the RAMS annual symposium. The goal of the workshop is to teach engineering college faculty to integrate reliability engineering design into their curriculum. This can be done by teaching engineers to design for reliability in the same way that they now design for function and efficiency. The workshop leaders will be leading academicians and industry executives. He is publicizing the workshop to 300 engineering colleges and suggesting that they provide grants to attendees. RAMS is supporting the effort by providing reduced fees for the symposium to those who attend the workshop. Dr. Bowles concluded by stating that the workshop will provide an opportunity to achieve some of the aims of this conference and asked that we each consider sponsoring an attendee.

DR. EDWARD J. HAUG, DIRECTOR, CENTER FOR SIMULATION AND DESIGN OPTIMIZATION, CENTER FOR COMPUTER AIDED DESIGN, COLLEGE OF ENGINEERING, UNIVERSITY OF IOWA, IOWA CITY, IOWA

Dr. Haug described the work being done by the University of Iowa related to the basic R&M design functions. Dr. Haug is also deeply involved in the "Symposium of Mechanical Systems for R&M," scheduled for October of 1989. It will include topics such as "R&M CAD: Best Served at the Graduate level, a Mechanical Engineering View." He feels that there are several major impediments to enhancing R&M in the mechanical engineering academic world. Many of the R&M concepts are not well known by current faculty members, and many faculty members have little or no experience with industrial requirements. New engineering technologies such as RAMCAD are not accepted by traditionalist faculty members as being in the "cutting-edge research" area. He stated that there are many opportunities to introduce these new technologies into academic R&M areas if organizations like the National Science Foundation keep the emphasis on design, if industry keeps stressing the importance of concurrent engineering, and if the CALS thrust continues to grow.

Panel Discussion: All Participants

An interactive dialogue led to the following general observations:

1. The Air Force is vitally concerned with the education of the next generations of engineers.

2. Academia is concerned with and working towards the evolution of the curriculum to satisfy professional and industrial needs, but does not wish to see a revolution in educational approaches.

3. All agreed that both industry and government have a major role and responsibility for research, which will stimulate change in the academic arena.

4. All were concerned with the pace of improvement, its relationship to the perceived national priorities in education, and with the question of whether the pace of improvements is a high or low priority.

5. Academia pointed out that funded research translates to papers, books, and curriculum technique introduction.

6. All agreed that important improvement factors include: ABET support, recruiter requirements (i.e., user needs), research and development funding, faculty initiatives, and national awareness.

7. All agreed that there are no "simple solutions;" that government, academia, and industry all have roles and responsibilities for engineering education improvement.

IV. PROSPECTS FOR CURRICULA INTEGRATION

VPI, FIT, UM, UI, and USAFA all presented significant progress in defining and developing sample reliability and maintainability curricula and in integrating the curricula into undergraduate engineering programs. Academia as a whole, however, does not seem predisposed to build on this progress. As an indicator, fewer academic institutions (8) attended this conference than government ones (10).

Those academics who did attend described the environment of their many colleagues who didn't. A college teacher's career depends primarily on the ability to publish, to support graduate students, and success at teaching, in that order. Much discussion centered on how to influence the teaching of quality-related engineering, given these constraints.

Four approaches emerged:

1. Customer Preference. The Air Force representatives repeatedly suggested that industry require specific capabilities of the engineering graduates they recruit. Although some industry participants said they were attempting to require supportability expertise, in reality, any decent engineering graduate can find a job with a good starting salary independent of specific curriculum. Demand for engineers will only increase in the near future, sustaining the seller's market.

2. New Accreditation Requirements. The panel repeatedly cited ABET for their success at instilling design projects into undergraduate engineering curricula. The group questioned if the ABET could next require some supportability-related curricula? The answer was yes, but not in the near term. For the ABET to take such an initiative, its 21 participating societies must first agree. As a point of reference, the incorporation of design projects into curricula took approximately 10 years.

3. Supportability Research Funding. Government or industry funding of related research at universities could allow teachers to both publish and support graduate students, while becoming conversant in supportability issues. Once conversant, all agreed teachers would naturally flavor undergraduate courses with these areas of interest. The Air Force responded, however, that supportability-related research was of low priority in the basic (largely college-based) R&D area. This isn't likely to change soon. Industry prefers to do most of its independent research in-house. The academics repeatedly pointed to the perception of their colleagues that Air Force and industry words didn't coincide with their actions.

4. Motivation. The popular press is increasingly publicizing the "quality gap" in US industry and the flight of our industrial base overseas. Perhaps more academics will develop an interest in teaching supportability-related engineering, in spite of competing priorities for their time, because it is essential to close this gap. The academians who attended AFIT summer workshops form a cadre of concerned teachers. They appear to be, however, a small and only slowly-growing minority among their peers.

None of these influences are thus likely to have significant near-term impact on the incorporation of supportability engineering into undergraduate engineering curricula in the majority of colleges and universities. They will undoubtedly have cumulative influence by the turn of the century. Thus, the panel recommended pursuing them all in whatever limited ways were possible. Meanwhile, the curricula development efforts must proceed apace to aid those programs which do exist, and to set good examples for others. In the near term, most supportability engineering will continue to be taught by industry as continuing education.

V. SUMMARY

The participants all agreed that the workshop had provided a forum for placing the need for supportability engineering curriculum for the 1990s into perspective. They were heartened by model programs at the Florida Institute of Technology, the Virginia Polytechnic Institute, the Unites States Air Force Academy, the University of Maryland, the University of South Carolina, and the University of Iowa. The participants recognized the role that R&D funding from government and industry plays in technology development, faculty career tracks, and promotions. They also recognized, however, the economic realities of governmental limitations in the Graham-Rudmann environment.

In order to achieve and sustain engineering curriculum improvement, the interaction of government/academic/industry teams to work solutions to the ongoing problems must continue on a recurring basis, even in periods of low funds availability.

The workshop closed on the observation that curricula integration is an ongoing problem without an easy solution, but one that must be addressed within the limits of the real world. There will be no dramatic new thrusts at this time, but all participants are committed to the recognition of the role of R&M in the design engineer's "tool-kit." "Quality" and "robustness" of products/systems, both in the private and public/defense sectors, are of paramount national concern.

APPENDIX A: LIST OF ATTENDEES

RAMCAD CONFERENCE - 14,15 JUNE 1989

	COMPANY/UNIVERSITY	NAME	MAILING ADDRESS	CITY, STATE, AND ZIP	TELEPHONE
A	FIT/Operations Research	Buoni, Fred, Dr.	150 W. University Blvd	Melbourne, FL 32901	407-768-8000x7390
A	FIT/Elec & Computer Engr Div	Hadjilogiou, John, Dr.	150 W. University Blvd	Melbourne, FL 32901	407-768-8000x7331
A	FIT	Mense, Allan, Dr.	150 W. University Blvd	Melbourne, FL 32901	407-768-8000x8043
A	Howard University	Gill, Tepper, Dr.	2300 6th St N.W.	Washington D.C. 20059	202-636-6585
A	Memphis State University	Bray, Charles, Dr.	2875 Cherry	Memphis, TN 38118	901-678-2175
A	Seattle University	Hearan, Robert, Dr.	8405 Alva SW	Tacoma, WA 98498	206-588-8128
A	University of Iowa	Haug, Ed, Dr.	Center for CAD, College of Engr	Iowa City, IA 52242	329-335-5725
A	University of Maryland	Pecht, Mike, Dr.	ME Dept, University of Maryland	College Park, MD 20742	301-454-8866
A	University of South Carolina	Bowles, John, Dr.	Electrical & Computer Engr. USC	Columbia, SC 29208	803-777-2689
A	Virginia Polytechnic Institute	Blanchard, Ben S., Profess	College of Engr, 333 Norris Hall	Blacksburg, VA 24061	703-231-5458
A	Virginia Polytechnic Institute	Fabrycky, Wolt, Dr.	302 Whittemore Hall	Blacksburg, VA 24061	703-231-6147
A	Virginia Polytechnic Institute	Verma, Dinesh, Dr.	I.E.O.R	Blacksburg, VA 24060	703-953-1478
G	AFALD	Loose, Don, Capt	AFALD/ER	WPAFB, OH 45431	513-255-6718
G	AFIT	Williams, Ben, Dr.	RQ	WPAFB, OH 45433	513-255-5836
G	Air Force Human Resources Lab	Kelly, Tim, 2d Lt	AFHRL/LRS	WPAFB, OH 45433	513-255-3611
G	Air Force Human Resources Lab	Lowdermilk, Don, Major	AFHRL/LRS	WPAFB, OH 45433	513-255-3611
G	National Science Found.	Ernst, Edward W., Dr.	1800 G St. N.W.	Washington D.C. 20550	202-357-7051
G	Nav Surf Warfare Ctr	Keiner, Bill, Mr.	Code E302	Dahlgren, VA 22448	703-663-8836
G	RADC/RBET	Caroli, Joe, Mr.	RADC/RBET	Griffiss AFB, NY 13441	315-330-4205
G	RADC/RBET	Klion, Jerry, Mr.	RADC/RBET	Griffiss AFB, NY 13441	315-330-4726
G	US Army/AMCCOM	Markowitz, Sid, Mr.	AMCCOM	Picatinny, NJ 07806-5000	201-724-2370
G	USA SEL	Peek, Jerry, Mr.	ATTN:AMXMC-SEL-E	Texarkana, TX 75507-5000	214-334-2001
G	USAF Academy	Skeith, William, Maj.	HQ USAFA/DFMS	USAFA, CO 80840	719-472-4470
G	USAF/LE-RD	Collins, William, General	Special Asst for R&M, Pentagon	Washington D.C. 20330	202-695-1171
G	USAF/LE-RD	Harrington, Jim, Col	Pentagon	Washington D.C. 20330	202-695-1171
G	USAF/LE-RD	Johnson, Bruce, Capt.	Pentagon	Washington D.C. 20330	202-697-9388
I	Electronic Industries Assoc.	Nucci, Ed J., Mr.	1722 Eye St. N.W.	Washington D.C. 20006	202-457-4965
I	Giordano Assoc., Inc	Giordano, Paul, Mr.	2301 Jeff Davis Highway	Arlington, VA 22202	703-521-1358
I	Giordano Assoc., Inc	Granieri, M., Mr.	2301 Jeff Davis Highway	Arlington, VA 22202	703-521-1358
I	Giordano Assoc., Inc	Neumann, George, Mr.	2301 Jeff Davis Highway, Dept 14	Arlington, VA 22202	703-521-1358
I	Giordano Assoc., Inc	Woodfine, J., Mr.	2301 Jeff Davis Highway	Arlington, VA 22202	703-521-1358
I	Harris Corporation	Ruttenberg, Franklin E., Dr	P.O.Box 883	Melbourne, FL 32902-0883	407-729-5463
I	Institute for Defense Anal	Hill, W., Mr.	1801 N. Beauregard St.	Alexandria, VA 22311	703-845-2092
I	Institute for Defense Anal	Richter, Karen J., Dr.	1801 N. Beauregard St.	Alexandria, VA 22311	703-845-2286
I	MITRE	Roome, Theodore, Mr.	M.S.H164, PO BOX 208	Bedford, MA	617-271-3194
I	Rockwell Industries(AS&ASD)	Walker, Dick, Mr.	Miraloma One	Anaheim, CA	714-779-3550
I	Systems Exploration, Inc.	Shapiro, Ted, Mr.	Suite 312, 5200 Springfield Pike	Dayton, OH 45431	513-256-5357

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APPENDIX B: AGENDA

AGENDA

June 14-15, 1989
Howard Johnson Hotel
Arlington, Virginia

THEME: ENGINEERING EDUCATION FOR THE 1990'S: INTEGRATING QUALITY THROUGH R&M DIMENSIONS

Day 1:

0800 - 0830		Registration
0830 - 0840		Kickoff/Welcome: Jerry Klion - RADC and Major Lowdermilk - AFHRL
0840 - 1000		"Industry's Engineering Needs for the Future"
	0840 - 0920	Dr. Vega - V.P. Engineering, GD-Convair
	0920 - 1000	Paul Giordano - President, Giordano Associates
1000 - 1015		Break
1015 - 1020		Administrative Announcements
1020 - 1100		AF Goals and Objectives toward Quality Achievement: General Collins - USAF LE-RD
1100 - 1145		"Abet's Point of View and Encouragement": Dr. Edward W. Ernst - President (Elect), Abet Program Director for Undergraduate Enginering Education, and National Science Foundation (NSF)
1145 - 1300		Lunch
1300 - 1330		Government Initiatives: AFHRL, RADC, and AFIT
1330 - 1415		"Past Efforts in Integrating R&M into Electrical and Computer Engineering Curriculum": Dr. Hadjilogiou - FIT
1415 - 1430		Break
1430 - 1515		"Efforts at Developing Curriculum Supportive of RAMCAD Thrust": Professor Ben Blanchard - VPI
1530 - 1630		Panel: "Definition of Curriculum Needs" Chairman: Col James Harrington - USAF LE-RD Academia: Dr. Haug - Iowa State University Industry: Dr. Franklin E. Ruttenberg - Harris Corporation
1630 - 1645		Recap: Adjourn

AGENDA

June 14-15, 1989
Howard Johnson Hotel
Arlington, Virginia

THEME: ENGINEERING EDUCATION FOR THE 1990'S: INTEGRATING QUALITY THROUGH R&M DIMENSIONS

Day 2:

0830 - 0840		Welcome, Announcements
0840 - 0920		"Academic Experience in Implementing Quality through R&M"
	0840 - 0910	LtCol Stephen R. Schmidt - USAF Academy
	0910 - 0940	Dr. Ben Williams - AFIT
	0940 - 1010	Dr. Michael Pecht - University of Maryland
1010 - 1030		Break
	1030 - 1100	Dr. Fabrycki - VPI
1100 - 1145		"Recap Definitions and Needs from Day 1 Panel": SEI Open Forum Discussion by all Participants
1145 - 1300		Lunch
1300 - 1530		Working Session: "A Look at Tommorrow - Where to Go and How to Get There":
		An Open Forum dedicated toward carrying defined needs forward, towards objectives, by defining areas of responsiblity for Academic, Industry, and DoD
1530 - 1600		Synopsis of Workshop Activity: SEI
1600		Adjourn